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for

PROGRAMMABLE CONTROLLER SYTEM AND METHOD FOR SUPPORTING VARIOUS OPERATIONAL MODES IN PERIPHERAL DEVICES

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PROGRAMMABLE CONTROLLER SYTEM AND METHOD FOR SUPPORTING VARIOUS OPERATIONAL MODES IN PERIPHERAL DEVICES

BACKGROUND OF THE INVENTION

[001] A computer system typically includes one or more printers that image a pattern onto a print medium such as paper, allowing users of the system to "print" hardcopies of various types of documents. Becoming increasingly popular in personal computer systems are multimode printers which, in addition to printing documents, also provide other functionality such as scanning, copying, and faxing of documents. A typical multimode printer includes a controller which performs image processing of images being processed by the printer and which also controls the operation of printing, scanning, copying, and faxing subsystems contained in the printer. The controller also communicates with a host computer system to which the printer is connected to receive image data to be printed and also to receive control inputs that control the operation of the multimode printer in the various operating modes. For example, a user of the host computer system may set the resolution of an image to be scanned during a scanning mode of operation or adjust the colors of contrast of a copy being made.

[002] The controller typically is formed from an application specific integrated circuit (ASIC) including a reduced instruction set computing (RISC) processor and custom image processing circuitry that operate in combination to execute various control and imaging processes to control the overall operation of the multimode printer. Typical imaging processes may include conversion from the red-green-blue ("RGB") color space to the cyan, magenta, yellow, and black ("CYMK") color space along with scaling and gamma conversion of the input image data, as will be appreciated by those skilled in the art. Typical control processes include control of the mechanical components of the printer subsystem, such as paper feeders and a print head, and the control of a scanning head during scanning of a document along with the generation of a corresponding image file.

[003] Conventional multimode printers have a fixed set of functionality defined by the firmware stored in memory in the printer and driver software running on the host computer system. The controller ASIC executes software instructions corresponding to the firmware so that the firmware and driver software collectively define the functionality of the printer. In such a system, an overall set of functions of the printer are fixed, with specific parameters then being selected and adjusted to control the various functions of the printer. As a result, the firmware executed by the controller in the printer must support all functions in this overall set, regardless of whether a particular function is being used at a given point in time. This results in more complex firmware and driver software to support this overall set of functions. More complex software and firmware may also necessitate a more complex controller ASIC in the form of a more complex image processing circuitry and a more powerful RISC processor. Furthermore, the more complex firmware increases the required capacity of memory in the printer for storing the firmware. A more complex controller and increased memory requirements all increase the cost of the printer. Moreover, in such a conventional multimode printer the operation of the printer controller and thus the set of overall functions supported by the printer are limited to a predefined set. The firmware for this set of functions must be stored in memory and available for execution by the controller even though only a small portion of the firmware corresponding to selected functions will actually be executing at any give point in time. Although the above description is directed to multimode printers, the concepts apply equally well to other peripheral devices in computer systems. For example, in a single mode printer which only prints documents the firmware for all the various functional modes, such as draft, letter quality, color, black and white, etc., must all be stored in the controller in the printer.

[004] There is a need for a reducing the cost of a printer or other peripheral device while also providing for flexible functionality of the device.

SUMMARY OF THE INVENTION

[005] One aspect of the present invention is a method of operating a peripheral device in a plurality of functional modes. The device may be part of a computer

system including a host computer and the method includes selecting a functional mode of the device. In response to the selection of the functional mode, firmware is transferred to the device, the firmware corresponding to the selected functional mode. The firmware is stored in the device and is executed in the device to operate the device in the selected functional mode. The device may be a printer or other peripheral device having a plurality of functional modes.

BRIEF DESCRIPTION OF THE DRAWINGS

[006] **FIG. 1** is a functional block diagram of a computer network including a printer containing a programmable print controller according to one embodiment of the present invention.

[007] **FIG. 2** illustrates a process executed by a printer program running on a host computer ***106*** in the computer network of **FIG. 1** and the programmable print controller in the printer for transferring selected firmware to the programmable print controller according to one embodiment of the present invention.

[008] **FIG. 3** is a flow chart illustrating an update routine executed during the process of **FIG. 2** for determining whether updated version of the firmware and the printer program are available and for downloading such firmware and printer program to the computer.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[009] **FIG. 1** is a functional block diagram of a computer network ***100*** including a printer ***102*** containing a programmable print controller ***104*** executing selected firmware to control the operation of the printer according to one embodiment of the present invention. The computer network ***100*** includes a host computer ***106*** that executes a printer program ***108*** which communicates with the programmable print controller ***104*** to transfer selected firmware and print data to the printer, and which also communicates with a Web server ***110*** to provide updated versions of selected firmware to the printer program and to install updated versions of the print program itself on the host computer, as will be explained in more detail below. In the

network ***100***, the printer ***102*** need only contain enough memory to store the firmware for any single function to be executed by the programmable print controller ***104***, reducing the overall capacity of memory required when compared to a conventional printer since the firmware for all functional modes of the printer need not all be stored in the printer. Moreover, the programmable print controller ***104*** allows for dynamic operation of the printer ***102*** since the firmware transferred to the controller can be updated. This allows the quality of operation of the printer ***102*** to be enhanced and new features to be added to the overall functionality of the printer.

[010] In the following description, certain details are set forth in conjunction with the described embodiments of the present invention to provide a sufficient understanding of the invention. One skilled in the art will appreciate, however, that the invention may be practiced without these particular details. Furthermore, one skilled in the art will appreciate that the example embodiments described below do not limit the scope of the present invention, and will also understand that various modifications, equivalents, and combinations of the disclosed embodiments and components of such embodiments are within the scope of the present invention. Embodiments including fewer than all the components of any of the respective described embodiments may also be within the scope of the present invention although not expressly described in detail below. Finally, the operation of well known components and/or processes has not been shown or described in detail to avoid unnecessarily obscuring the present invention.

[011] The programmable controller ***104*** includes control circuitry ***112*** that communicates with the printer program ***108*** executing on the host computer ***106***. The control circuitry ***112*** also executes firmware FW stored in a random access memory (RAM) ***114*** and generates a plurality of control signals to control the operation of the printer ***102***. Also stored in the RAM ***114*** is a version indicator "FW Version" indicating the version of the firmware being executed by the circuitry ***112*** along with a flag "FW Loaded Flag" indicating whether firmware is currently loaded in the RAM. The RAM ***114*** also stores image data ID which is processed by image

processing circuitry ***116*** under control of the control circuitry ***112***, as will be described in more detail below.

[012] The controller ***104*** further includes nonvolatile memory ***118*** that includes a plurality of programs and parameters executed and utilized by the circuitry ***112*** in controlling the operation of the printer ***102***. Stored in the nonvolatile memory ***118*** is a firmware download program FW Download Program that the circuitry ***112*** executes to download firmware FW from the host computer ***106*** and store the firmware in the RAM ***114***. The circuitry ***112*** also executes an integrity check program FW Integrity Check stored in the nonvolatile memory ***118*** to verify the validity or integrity of the firmware FW stored in the RAM ***114*** prior to executing that firmware. The nonvolatile memory ***118*** also stores data PC Version indicating the current version of the programmable controller ***114***.

[013] The control circuitry ***112*** also controls mechanical components ***122*** to generate an image corresponding to the image data ID. For example, the mechanical components ***122*** would typically include a print head for transferring ink onto paper and a paper feeder, and the control circuitry develops signals to control the operation of the mechanical components in printing an image on a piece of paper. The printer ***102*** further includes a user interface ***124*** that allows a user of the printer to provide selection inputs to control the operation of the printer. For example, the user interface ***124*** would typically include buttons that allow a user to turn the printer ***102*** on and off, to pause a print job, and so on, and may also include buttons to allow a user to apply a functional mode request to select a desired functional mode of the printer, such as a print, scan, copy, or fax mode where the print controller ***104*** and mechanical components ***122*** include subsystems to support these different functional modes of operation.

[014] The host computer ***106*** includes the printer program ***108*** which receives data to be printed from an application program ***126*** running on the host computer, and processes this data to transform the data into Printer-Ready Data that is stored in a memory ***128*** and thereafter transferred to the control circuitry ***112*** in the printer ***102*** for storage in the RAM ***114***. In addition, the printer program ***108*** also accesses data and programs stored in the memory ***128*** to control the transfer of selected

firmware FW to the printer ***102*** in response to the selection inputs. The selection inputs may be received from the circuitry ***112*** in the printer ***102*** where a user selects a functional mode via the user interface ***124***, or the selection inputs may be applied to the printer program ***108*** by a user of the host computer ***106***. The data stored in the memory ***128*** includes PP Version indicating the current version of the printer program ***108***, PC Version indicating the current version of the programmable controller ***104*** in the printer ***102***, and FW Version indicating the current version of the firmware that can be transferred to the programmable controller for execution. The operation of the printer program ***108*** in utilizing these various fields of data stored in the memory ***128*** will be described in more detail below. The actual firmware FW that may be transferred to the programmable controller ***104*** for execution is also stored in the memory ***128***, and is indicated as being formed by a plurality of individual firmware segments FW1-FWN. Depending upon the selected functional mode of the printer ***102***, only the corresponding one or ones of these firmware segments FW1-FWN are transferred to the controller ***104*** in the printer ***102*** for storage in the RAM ***114***, as will also be explained in more detail below.

[015] In the computer network ***100***, the Web server ***110*** communicates with the host computer ***106*** through a suitable communications network ***130***, such as the Internet. The server ***110*** includes Web site software ***132*** for interfacing with the host computer ***106*** and other computers communicating with the Web site corresponding to the web site software. The Web site software ***132*** allows the printer program ***108*** either automatically or under control of a user of the host computer ***106*** to access the server ***110*** and determine whether updates of the printer program ***108*** or firmware FW for the printer ***102*** are available. When such updates are available, the Web site software ***132*** transfers an update program ***134*** to the host computer ***106***. This update program ***134*** includes the latest versions of the firmware FW, printer program ***108***, which is designated PP in the memory ***134***, along with the latest versions of the firmware and printer program and the versions of the printer controller ***104*** with which these latest versions are compatible.

[016] The overall operation of the computer network ***100*** of **FIG. 1** will now be described in more detail with reference to **FIG. 1** and to the flowchart of **FIG. 2**.

FIG. 2 illustrates a process executed by the printer program ***108*** running on the host computer ***106*** and the programmable print controller ***104*** in the printer ***102*** for transferring selected firmware FW to the programmable print controller according to one embodiment of the present invention. Prior to the process of **FIG. 2** starting, it is assumed the application program ***126*** on the host computer ***106*** has provided data to be printed to the printer program ***108*** and/or a functional request corresponding to functional mode in which the printer ***102*** is to operate has been supplied to the printer program. For example, where the printer ***102*** is a multimode printer and includes scanning and copying functionality, the functional request from the application program ***126*** may correspond to a request generated by the printer program ***108*** to place the printer ***102*** into either the scan or copy functional mode of operation. In the following description, the functional mode of the printer ***102*** is assumed to be a print mode in which data supplied from the application program ***126*** is to be printed.

[017] When this occurs, the process starts in step ***200*** and proceeds to step ***202*** in which the printer program ***108*** formats the received data into a printer-ready form that may be processed by the programmable print controller ***104***. For example, the printer program ***108*** may format the data to be printed according to a page description language (PDL) such as the Printer Control Language (PCL) utilized by Hewlett-Packard or Postscript language utilized by Adobe, as will be appreciated by those skilled in the art.

[018] The process then goes to step ***206*** and the printer program ***108*** and circuitry ***112*** communicate to determine whether the firmware segment FW1-FWN corresponding to the selected functional mode of the printer ***102*** is already stored in the RAM ***114*** in the programmable print controller ***104***. To make this determination, the circuitry ***112*** reads the FW Loaded Flag stored in the RAM ***114*** and determines whether this flag is set indicating the firmware is loaded into the RAM or whether the flag is reset indicating the firmware is not loaded. If the determination is negative, the process goes to step ***208*** and the firmware segment FW1-FWN corresponding to the selected functional mode of the printer ***102*** is transferred to the processing control circuitry ***112*** which, in turn, stores the firmware in the RAM

114 and sets the FW Loaded Flag. The process then returns to step ***206*** where the determination of whether the proper firmware segment FW1-FWN is stored in the controller ***104*** is now positive and the process then proceeds to step ***210***. If the determination in step ***206*** is initially positive, then the process proceeds immediately to step ***210***.

[019] In step ***210***, the circuitry ***112*** executes the FW Integrity Check program to verify the integrity of the firmware segment FW1-FWN stored in the RAM ***114*** prior to executing this firmware segment, and provides an indication of the results of this integrity check to the software program ***108***. The process goes to step ***212*** and determines whether the integrity check was successful. If the integrity check was unsuccessful, indicating an error in the firmware segment FW1-FWN stored in the RAM ***114***, the process returns to step ***208*** and the firmware segment is once again transferred to the processing control circuitry ***112***. If the integrity check is successful, the process proceeds to step***218***.

[020] The printer program ***108*** then transfers the print-ready data stored in the memory ***128*** to the RAM ***114*** under control of the control circuitry ***112***. This print-ready data is stored in the RAM ***114*** as the image data ID and the image processing circuitry ***116*** then processes this data for printing. This processing would normally include steps such as color space conversions, image enhancements, and the execution of other algorithms necessary to prepare the data for printing, as will be appreciated by those skilled in the art. In one embodiment, the image processing circuitry ***116*** includes a digital signal processor for performing such image processing. The use of a digital signal processor provides flexibility in the operation and performance of the printer ***102*** since the image processing firmware FW for a given function (or combination of functions) can be downloaded into the controller ***104*** as needed.. In another embodiment of the image processing circuitry ***116***, the circuitry includes multiple digital signal processors operating in parallel to perform the required image processing. Parallel processing of the print-ready data improves the speed of the printer ***102***.

[021] Once the desired data has been printed on one or more pages in step ***220***, the process goes to step ***222*** and terminates. In one embodiment, when the

process terminates in step ***220*** the control circuitry ***112*** deletes the firmware segment FW1-FWN stored in the RAM ***114*** in anticipation of another functional mode of operation of the printer ***102*** being selected.

[022] With the programmable print controller ***104***, the printer ***102*** need only contain enough memory to store the specific firmware segment FW1-FWN currently being executed by the programmable print controller ***104***. In this way, the programmable print controller ***104*** allows only the firmware segment FW1-FWN corresponding to the selected functional mode of operation to be stored in the RAM ***114*** to operate the printer ***102*** in this functional mode. In contrast, with a conventional printer the firmware for all functional modes of the printer are stored in memory in the printer and only portions of this firmware are executed at any given time in response to the selected functional mode of operation. The programmable print controller ***104*** reduces the required capacity of the RAM ***114*** when compared to a conventional printer because only the firmware segment FW1-FWN for the selected functional mode must be stored in the RAM ***114***. As previously mentioned, the programmable print controller ***104*** also allows for dynamic operation of the printer ***102*** since the firmware segments FW1-FWN transferred to the controller ***112*** can be updated to improve the quality of operation of the printer ***102*** or to enhance or add features to overall functionality of the printer.

[023] **FIG. 3** is a flow chart illustrating an update routine executed by the printer program ***108*** of **FIG. 2** for determining whether updated versions of the firmware FW and the printer program are available, and for downloading such firmware and printer program to the host computer ***106***. Typically, this update routine would only be executed occasionally. For example, perhaps the update routine would execute every day at a predetermined time when it is unlikely a user will be using the host computer ***106***, such as at 3:00 AM when the user is sleeping or at 1:00 PM when the user is at work. The update routine could, of course, be executed in response to other conditions as well. The flowchart of **FIG. 3** will now be explained with reference to **FIGS. 1-3**. The update routine starts in step ***300*** and goes to step ***302*** to determine whether the host computer ***106*** is connected to the Internet ***130***. If the computer ***106*** is not connected to the Internet ***130***, then no updates may be

downloaded from the Web server ***110*** and the process goes to step ***304*** and then terminates in step ***306***. If the computer ***106*** is connected to the Internet ***130***, the update routine then determines whether an auto-update feature of the printer program ***108*** is enabled in step ***303***. The user of the host computer ***106*** can disable the auto-update feature if automatic updates for the printer program ***108*** and firmware FW are not desired, and in this case the process once again goes to step ***304*** and ***306*** and terminates.

[024] When the auto-update feature is enabled, the process goes to step ***305*** and the printer program ***108*** determines whether there are updated versions of the firmware FW and printer program available. In making this determination, the printer program ***108*** compares the PC Version for the programmable print controller ***104*** in the printer ***102*** to the PC Versions contained on the Web server ***110*** for which updates are available. If there are no updated versions available, the process once again goes to step ***304*** and ***306*** and terminates. When the printer program ***108*** determines in step ***305*** that updated versions of the firmware FW and printer program are available, the update routine goes to step ***307*** and determines whether the firmware version FW Version of the updated firmware is compatible with the version PC Version of the print controller ***104*** and the version PP Version of the software program. The versions FW Version, PC Version, and PP Version are all stored in the memory ***128*** in the host computer ***106***, and the software program ***108*** merely compares these versions in making this determination. If the determination in step ***307*** is negative, the process goes to steps ***304*** and ***306*** and terminates. In this situation, the updated firmware FW from the Web server ***110*** is for some reason incompatible with the controller ***104*** and other hardware in the printer ***102***.

[025] When the determination in step ***307*** indicates that the FW Version is compatible with the PP version and the PC Version, the process goes to step ***308*** and downloads these programs from the Web server ***110***. From step ***308*** the process goes to step ***312*** and the first thing the update routine does is to perform an integrity check of the new firmware FW stored in the memory ***128*** on the host computer ***106***. If the integrity check fails in step ***314***, meaning that an error exists

in the updated firmware FW downloaded from the Web server ***110***, the process once again goes to step ***304*** and ***306*** and terminates.

[026] When step ***314*** determines the integrity check of the new firmware FW has passed, indicating no errors in the updated firmware FW downloaded from the Web server ***110***, the process goes to step ***316*** and the update routine stores a copy of the updated firmware FW in the memory ***128*** on the host computer ***106***. At this point, the update routine installs the updated version of the printer program ***108*** on the host computer ***106*** and initiates execution of this new version of the printer program. The updated version of the printer program ***108*** now executes on the host computer ***106***, and the process then goes to step ***306*** and terminates.

[027] Even though various embodiments and advantages of the present invention have been set forth in the foregoing description, the above disclosure is illustrative only, and changes may be made in detail and yet remain within the broad principles of the present invention. Moreover, the functions performed by the blocks illustrated in **FIG. 1** can be combined to be performed by fewer elements, separated and performed by more elements, or combined into different functional blocks depending upon the actual components used in the printer ***102*** and computer network ***100***, as will appreciated by those skilled in the art. Therefore, the present invention is to be limited only by the appended claims.